UNDERGRADUATE FINAL YEAR PROJECT REPORT

Department of Electrical Engineering, Indus University
Faculty of Engineering Science and Technology(FEST), Indus University

ELECTRONIC TONGUE TASTE SENSOR For Quality Analysis Using Machine Learning

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CERTIFICATE

This is to certify that the project namely **"E-Tongue Taste Sensor For Quality Ananlysis Using Machine Learning"** presented by **Tasneem Mustansir, Saleem M Shaikh and Ajlal Hyder** under the direction of their project advisor's and approved by the project examination committee, has been presented to and accepted by the Department of Electrical Engineering, Faculty of Engineering Science & Technology, Indus University, in partial fulfillment of the requirements for Bachelor of Electrical (Electronics) Engineering. Plagiarism test was conducted on complete report, and overall similarity index was found to be less than 20%, with maximum 5% from single source, as required.

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AUTHOR'S DECLARATION

This project **"ELECTRONIC TONGUE TASTE MACHINE (FOR WATER PURIFICATION)"** was presented by **Tasneem Mustansir (2408-2019), Saleem Muhammad Shaikh (2449-2019)** and **Ajlal Hyder (2485-2019).** We affirm that we are the exclusive authors of this project, and it represents the unaltered version that received approval from our supervisor(s), including any required modifications. Furthermore, we hereby provide Indus University with authorization to duplicate and disseminate electronic or hard copies of this project.

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STATEMENT OF CONTRIBUTIONS

We extend our dedication of this project to the Almighty Allah, our creator, our steadfast support, and the source of our inspiration, wisdom, knowledge, and insight. Additionally, this work is a tribute to our family, whose unwavering encouragement has fueled our determination to see this endeavor through to its completion. Special thanks are due to our teachers, who have been a constant presence throughout our entire bachelor's program, providing invaluable support and encouragement. In unison, we dedicate our project to our cherished parents, who have showered us with unwavering love and support since our birth, guiding us through every step of life.

Project leader (Tasneem Mustansir):

- Provided overall project direction and vision
- Managed project timelines and resources
- Oversaw collaboration among team members
- Ensured the project met its objectives and milestones
- Conducted rigorous testing of the E-tongue prototypes
- Worked on data acquisition and transmission capabilities
- Conducted extensive literature reviews on taste sensors

Group Member (Saleem M Shaikh):

- Ensured the device was portable and user-friendly
- Integrated the taste sensors into the electronic system
- Collaborated with the electronics team on sensor integration
- Conducted experiments to refine sensor sensitivity

Group Member (Ajlal Hyder):

- Created visualization tools to represent taste profiles
- Worked on the device's compatibility with external devices.
- Conducted a detailed market survey

ABSTRACT

In response to the pressing challenges faced by industries like food, beverages, and pharmaceuticals, our project introduces the E-Tongue Taste Sensor—a remarkable innovation inspired by the human gustatory system. Unlike the limited capabilities of the human tongue, this electronic counterpart can discern a wide array of taste attributes, including sourness, sweetness, bitterness, saltiness, pH levels, umami, total dissolved solids (TDS), and turbidity. Emerging at the intersection of food engineering, sensor fusion, and artificial intelligence (AI), our project aims to enhance product quality and measurement precision across these fields.

It addresses critical issues such as reliance on subjective human sensory assessments, the need to mask bitterness in pharmaceutical components, and the ensuing compromises in product quality and quantity. With objectives spanning from ensuring product safety through pH measurement to refining taste characteristics and monitoring astringency, our project paves the way for improved quality in food, beverages, and medicine.

The E-tongue's functionality involves the conversion of taste attributes into electrical signals, which are then processed by a machine learning model to generate comprehensive taste profiles. In conclusion, the E-tongue taste sensor offers a groundbreaking solution that replicates human taste perception, providing objective evaluations, eliminating bias, accelerating evaluations, and enhancing versatility across various industries. Its potential for transforming quality control practices is significant and promising.

ACKNOWLEDGEMENT

All Praises and thanks to the almighty **"ALLAH",** the most benevolent, the most kind, the wellspring of information and insight supplied by humanity, who has blessed us with the force of the psyche and the ability to take this endeavor to the shocking breadth of data. All regards are to our most beloved Prophet **"Hazrat MUHAMMAD (Peace Be Upon Him)",** whose character will continuously be a wellspring of direction for mankind.

Affirmation is because of the **Faculty of Engineering Science & Technology** for the help withthis Task, a profoundly valued accomplishment for us at the undergrad level.

We wish to communicate our appreciation to our supervisor (**Engr. Shoaib Hussain Zaidi**) who filled in as our significant counselor. We might want to offer our heartiest thanks for their sharp direction, genuine assistance, and Cordial way which rouses us to do well in the venture and makes it a reality.

Many individuals, particularly our classmates and teammates, have offered essential ideas on thisproposition, which motivated us to work on our task. We thank Co-Supervisor **(Engr. Sajid Ahmed)** Internal Expert **(Engr. Saifullah Burrero)** & every individual for their assistance straightforwardly and in a roundabout way in finishing our project.

DEDICATION

We dedicate this thesis to our families, whose unwavering support and encouragement have been the driving force behind our academic journey. To our friends and mentors, who have shared their knowledge and wisdom, helping us navigate the challenges of research and academia. And to all those who believe in the power of knowledge and the pursuit of excellence, may this work contribute in some small way to our collective understanding of the world.

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LIST OF ABBREVIATIONS

WHO	World health organization
ML	Machine learning
AI	Artificial Intelligence
TDS	Total Dissolved Solids
pH	Potential of Hydrogen
IR	Infrared
TFT	Thin Film Transistor
LCD	Liquid Crystal Display

CHAPTER 1

INTRODUCTION

Our project mimics human's gustatory system. On human tongue there are taste buds which carry the process of tasting, the very sensitive microscopic hairs called microvilli on taste buds which sense and indicate whether our food is sour, sweet, salty or bitter. E-tongue taste sensor artificially reproduces the taste sensation. A human tongue is capable of identifying only four characteristics of food whereas, an electronic tongue can sense sourness, astringency, bitterness, saltiness, pH, umami, TDS and turbidity. E- tongue taste sensor originates from three emerging fields worldwide: food engineering, sensor fusion and AI. In this regard our project contributes to all these fields by giving an analysis on quality enhancement and quantity measurement.

1.1 Problem Statement

Industries operating within sectors such as food, beverages, and pharmaceuticals encounter a significant challenge in effectively discerning crucial characteristics of samples, including attributes like sourness, sweetness, bitterness, saltiness, pH levels, umami, TDS and turbidity. Presently, the absence of a comprehensive sensing device in Pakistan forces these industries to compromises in both the quality and quantity of the final products. A pertinent example lies in the pharmaceutical, where the inherent bitterness of certain elements necessitates the addition of supplementary components to render them consumable. However, gauging the degree of bitterness and its palatability for human consumption remains an unresolved concern causing following problems:

- Relying on human sensory assessments is inadequate and potentially hazardous.
- pharmaceutical components can exhibit extreme bitterness, prompting the addition of other substances to make them consumable.
- Leading industries to compromise in both the quality and quantity the products.

1.2 Motivation

There are two motivations behind this project:

1. Sometimes a product is manufactured without being tested properly. Consumer purchase the product unknowingly that this batch could be not up to the mark.

There were several reports filed in Pakistan that "Lack of interest of regulatory authorities in the developing countries such as Pakistan and India render theses adulterated; a technique which suppresses the health promoting ability of milk and dairy products and transforms it into hazardous and noxious effects" [1]. As a result, of E-tongue taste sensor machine, detects adulteration and contamination of natural healthy items can be avoided. The motivation is to provide better product to the consumers and improve the quality a consumer intake.

2. Another, motivation behind this project was that all the recent research is been done in mimicking human being and improving those capabilities artificially as it's the best example set by nature.

Most of the technology such a humanoid robot, robotic arm, E-tongue, E-nose are based on the best example; human. Even a controller which is used in every engineering project is inspired by human brain. "The primary method for the taste measurement of a drug substance or a formulation is by human sensory evaluation. However, this method is impractical for early stage drug development because they are expensive, time consuming and the taste of a drug candidate may not be important to the final product. Therefore, taste-sensing analytical devices, which can detect tastes, have been replacing the taste panelists" [2]. As students, following new research trend is a motivation for us and bring some innovation in it is the inspiration.

1.3 Industrial Visit Analysis

Visited Industry Profile:

Figure 1 SAMI Pharmaceuticals Logo

SAMI Pharmaceuticals emerged as a trailblazer in the pharmaceutical landscape of Pakistan, challenging the long-standing dominance of multinational corporations in the post-independence era. This transformative journey dismantled the notion that only large multinationals could deliver top-quality pharmaceutical products. SAMI disrupted this narrative by introducing a novel approach, delivering exceptional products at prices that respect the nation's resource limitations. The company's dedication to producing quality branded generics has led to the ascension of several products to leadership positions within their respective categories.

Observations of Visit:

I. The local industries do not use any method by which they can identify the taste of the medicine.

II. There are no methods for spoilage detection of any herb.

III. Some of the manufactured medicines do have complains that the taste is very bitter and is difficult to consume by customers.

IV. Traditional methods of quality testing are proven to be time-consuming, subjective, and often fall short of providing the comprehensive insights required.

V. Human testers are struggle to detect subtle variations in flavor, taste, or composition, especially when dealing with complex pharmaceutical formulations.

VI. Conventional quality assessment methods demand considerable time and human resources.

VII. Human testers' perceptions can be influenced by factors such as fatigue, mood, and personal preferences, leading to inconsistent results.

Figure 2: Manufacturing process of medicines

Industrial Visit Conclusion:

In conclusion, the industrial visit was completed in a pleasant way, each employee answered the queries concerned with them. It is a well-established pharmaceutical company and have great system of manufacturing. But, the pharmaceutical companies face significant challenges in maintaining product quality, consistency, and efficiency without the use of E-Tongue technology. The subjective nature of traditional testing methods, coupled with the inefficiencies they introduce, can hinder the industry's ability to deliver safe, effective, and consistent pharmaceutical products.

1.4 Objectives

- Measuring the pH level of the sample so that it's not harmful for consumption.
- Detecting the presences of total dissolved solids in the given sample which will help to improve the quality of the product.
- Sensing the characteristics of sample such as sourness, sweetness, bitterness and saltiness to improve the taste.
- Monitoring of astringency(acidity), umami (meat like taste), and turbidity of the sample.
- Aiming to improve quality of the food, beverage and medicine.
- And, to use appropriate quantity of elements in the consumable items.

Figure 3: Representation of our objectives in a form of logo.

1.4 Organization of Thesis

The organization of the “E-Tongue Taste Sensor For Quality Analysis Using Machine Learning” report is divided into five sections. The details of the sections are as follows:

- Chapter one of this report comprises the introduction and the problem discussion in detail. We have also added the motivation that motivated us to work on this project. Further, we have discussed the main objectives in this section.
- Chapter two consists of literature review: background and latest work done by researchers.
- Chapter three includes experimental setup and procedure: methodology, block diagram, flowchart and schematic diagram, hardware components, project costing and project design.
- Chapter four consists of the results and discussion: the system analysis parameters and system specifications.
- Chapter five has the conclusion and future work related to the project.

CHAPTER 2

LITERATURE REVIEW

Taste is a critical factor in food and beverage products, and its measurement is vital for quality control and product development. Electronic tongues, or E-tongues, have emerged as a promising tool for taste analysis, providing a fast, accurate, and objective measurement of taste attributes. In this preliminary literature review, we will explore the current state of research on E-tongue taste sensors and their applications in food and beverage industries.

2.1 Electronic tongue a gustatory tool:

The old and primary method of tasting and formulation was done by human called panelists but it was very problematic process in industry and this was due to the potential toxicity of drugs and subjectivity of taste panelists, problems in recruiting taste panelists, motivation and panel maintenance are significantly difficult when working with odious products. E-tongue taste sensor is a replacement of this sensory panelists. In this review article first we discussed the structure of human tongue and it's working. Human tongue was further compared with E-tongue taste sensor which is an instrument trained for processing the taste attributes in less time. It consists of sensory array, the equipment of emitting and receiving signals, and pattern recognition. Human tongue sense and that information is transmitted to the brain where the picture of sensed object is created. Hence, artificial intelligence acts as an electronic brain for E-tongue taste sensor. This paper also mentions valuable application of E-tongue in pharmaceuticals, food industries, medical industry, in agriculture, beverage industry and also in explosive & weapon. [3]

2.2 Electronic Tongue to Evaluate Taste of Soybean Genotypes:

An Electronic tongue is fast and efficient method of analyzing the taste of a sample. In this paper E-tongue taste sensor was used to evaluate the flavor of soybean and its genotypes. A sample was made by 25 grains of soybean added to 100mL of distilled water. For determination two methods were conducted;

1)Three methods for extracting flavor were assessed to expedite flavor analysis across a substantial sample pool using the Electronic Tongue (ET). 2) Lines from the breeding program were scrutinized to confirm the effectiveness of chemical sensors in distinguishing flavor variations among these lines.

In experiment 1 three samples were made bad flavor, good flavor and superior flavor and the result suggested that for better result E-tongue taste sensor should take 5 min, which could improve flavor extraction without intruding in time consuming analyses by ET system. In experiment 2 the samples of dried soybean grains of the 25 genotypes with different flavor characteristics were milled and extracted and this sample was tested. The E-tongue system was able to distinguish soybean flavor differences. Hence, from these experiments and research we can conclude that an easy method for flavor extraction is important to improve the analyzes by the electronic tongue system. [4]

2.3 Bio electronic Tongue Using Heterodimeric Human Taste Receptor:

This paper delves into the recent strides made in comprehending taste detection mechanisms and the emulation of this ability through artificial sensor devices. It specifically explores the development of a bioelectronics tongue that utilizes heterodimeric human sweet taste receptors. This innovative approach allows the detection and differentiation of sweeteners with performance closely resembling human capabilities. The sweetener sensor resulting from this research exhibits remarkable sensitivity and a broad selectivity spectrum, recognizing a wide array of sweeteners, both natural and artificial. This pioneering strategy holds the potential to overcome the limitations typically associated with conventional artificial tongues, particularly in terms of sensitivity and selectivity. Moreover, it presents practical applications within the food and beverage industry. As such, this Nano vesicle-based bioelectronics tongue emerges as a potent tool for sweetener detection, offering an alternative to labor-intensive and time taking methods such as cell-based assays and sensory evaluation panels commonly used in the food and beverage sector. [5]

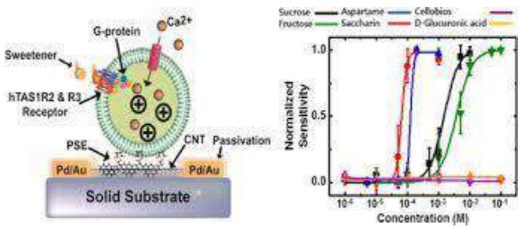


Figure 4 Heterodimeric Human Taste Receptor precision

2.4 Artificial Taste Sensor in Evaluating the Bitterness of Drugs:

Haraguchi et al. (2018) based their research on the observation that the taste of medications is essential in producing therapeutic formulations that are meant to be taken orally. Massive efforts have been made by both the pharmaceutical industry and academic organizations to create drugs that obscure their taste. However, the unpleasant taste of pharmacological substances is a persistent cause of non-compliance explore and evaluate the ability of the artificial taste sensor. The human sensation test is the standard method for gauging the bitterness foods and medicines. This approach has ethical and toxicological concerns, subject burden, and the need to account for inter-subject variability. For this reason, artificial instrumentation for assessing taste has gained popularity. Their research aimed to compare the responses of the artificial taste sensor to those of previously documented human TASTE2 receptors (hTAS2Rs) in order to assess the taste sensor's capacity to judge the bitterness of medications. For their research 22 bitter compounds were selected and five unique taste detectors (AC0, AN0, BT0, C00, AE1) were used to evaluate the solutions (0.01 mM, 0.03 mM, and 0.1 mM). The compounds' physicochemical properties and the responses of the taste sensors and hTAS2Rs were analyzed. [6]

2.5 Electronic tongue with lipid membranes:

This report introduces an E-tongue equipped with lipid membranes, aptly named the "taste sensor" due to its capacity to emulate the sensory type consistency found in the gustatory system of humans, known as global selectivity. An exploration of the membrane surface's structure is undertaken through optical techniques, offering insights into the response mechanisms that could inform future membrane design. Furthermore, a novel psychochemical modification (preconditioning) is considered to enable the membrane to respond to unaltered taste substances. The paper is structured as follows: firstly, it elucidates the sensing process of the taste sensor, its utility in evaluating beer, and the underlying measurement methodology. Secondly, recent findings are presented, encompassing the sensor's application in detecting high-potency sweeteners and enhancements made to the bitterness sensor. Finally, the report delves into quantifying the bitterness-masking effect of high-potency sweeteners, employing regression analysis based on both bitterness and sweetness sensor outputs. In essence, the taste sensor offers a biomimetic approach distinct from conventional analytical methods. [7]

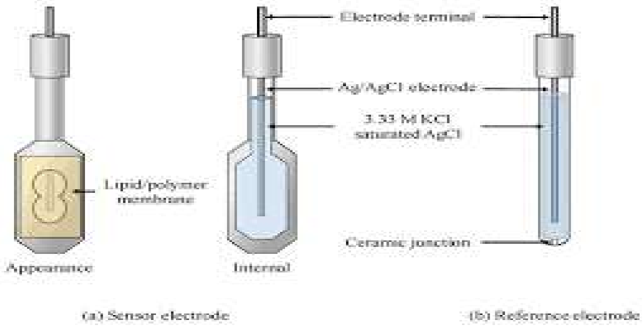


Figure 5 Sensor electrode
(a) reference electrode
(b) taste sensor.

2.6 Atrazine level Detection in Drinking Water by E-Tongue:

In numerous countries, the presence of atrazine in agricultural areas has raised concerns due to its detection in groundwater and even drinking water, potentially affecting generations to come. This research paper highlights that atrazine levels in 44.4% of groundwater and 11.1% of bovine milk (n = 18) exceeded internationally established safety limits for human consumption. Notably, in both types of samples, the hazard quotient (HQ) and cancer risk (CR) associated with residual atrazine were more for children compared to grown people. This marks the first documented instance of residual atrazine in bovine milk in Argentina. The findings underscore the importance of continued monitoring of atrazine contamination in the region to evaluate its potential long-term implications for public health. It's worth noting that atrazine levels exceeding 3ppb were observed to elevate both the sweetness and pH of the water. [8]

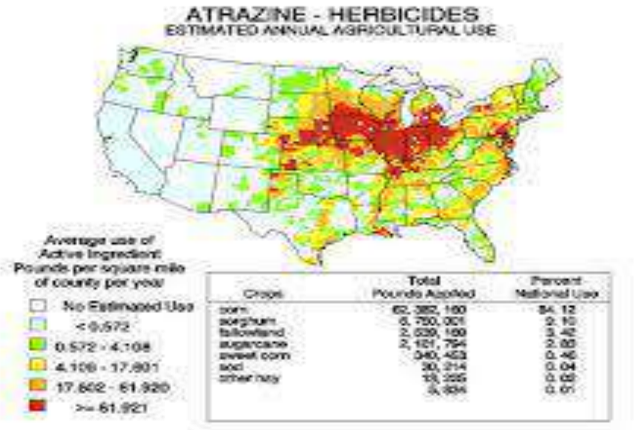


Figure 6 Atrazine level Map in US

2.7 Detection of taste attributes in variety of food products:

In this article the authors begin by introducing the concept of E-tongue and its history, highlighting its ability to mimic the human sense of taste and detect taste attributes in a variety of food products.

The article then delves into the principles of E-tongue technology, describing the different types of sensors used and their sensing mechanisms. The authors also discuss the importance of data analysis and pattern recognition algorithms in E-tongue technology, as these are critical for accurate and reliable taste analysis. Furthermore, the authors discuss recent advancements in E-tongue technology, including the integration of nanomaterials, microfluidics, and artificial intelligence (AI) algorithms. They also discuss the potential future directions of E-tongue technology, such as the development of portable and low-cost devices for on-site taste analysis. [9]

2.8 The latest developments in E-tongue technology:

The authors in this paper discuss the latest developments in E-tongue technology, including new sensor materials such as graphene-based sensors, advances in signal processing techniques such as machine learning and artificial neural networks, and the integration of E-tongue with other analytical techniques such as mass spectrometry and chromatography. The paper also discusses the applications of E-tongue technology in various fields such as healthcare, environmental monitoring, and food analysis. The authors describe how E-tongue technology can be used for detecting disease biomarkers in body fluids, monitoring water quality, and evaluating food quality and authenticity. [10]

2.9 Detection of the black pepper using E-Tongue:

The paper [11] proposes a novel approach for the detection of the origin of black pepper using a combination of electronic sensory devices, machine learning techniques, and an attention process. The paper highlights the importance of black pepper as a widely used spice and the challenges associated with the authentication and traceability of its origin. The authors describe their approach of using an Electronic tongue, nose, and eye to collect sensory data from black pepper samples, followed by feature extraction and selection using principal component analysis (PCA) and linear discriminant analysis (LDA). The paper also introduces a convolutional neural network (CNN) model combined with an attention mechanism for feature selection and classification. The outcome of the study demonstrate that the proposed strategy achieved high accuracy in the detection of the origin of black pepper, outperforming traditional mechanism such as gas chromatography-mass spectrometry (GC-MS).

2.10 E-Tongue with Machine Learning Techniques and Their Applications:

The article discusses the recent developments in electronic tongue technology, including improvements in sensor materials, sensor arrays, and data analysis algorithms. The authors also describe the various applications of electronic tongues in different fields, such as food and beverage industry, environmental monitoring, and medical diagnostics. In light of E-tongue, the article concludes that electronic tongues have great potential in the field of food and beverage industry, as they can be used for quality control, product authentication, and sensory analysis. The authors also highlight the potential applications of electronic tongues in medical diagnostics, such as the detection of diseases and the monitoring of drug levels in the body. [12]

Summary:

All in all, we learned a lot about the E-tongue taste sensor from the above papers. Our project hardware is the extension work of [13] report. The sensor we developed which senses the sweetness, saltiness, sourness, bitterness and umami is constructed with the help of this paper. There are many approaches by which we can generate these results as discussed in above papers but we have used IR sensor technique for custom built sensor. The method makes our machine cost effective and also gives required results. Further we have made our machine efficient artificially intelligent by using machine learning. We can predict by its parameters that which kind of sample it is given to the machine.

CHAPTER 3

EXPERIMENTAL SETUP AND PROCEDURE

3.1 Methodology:

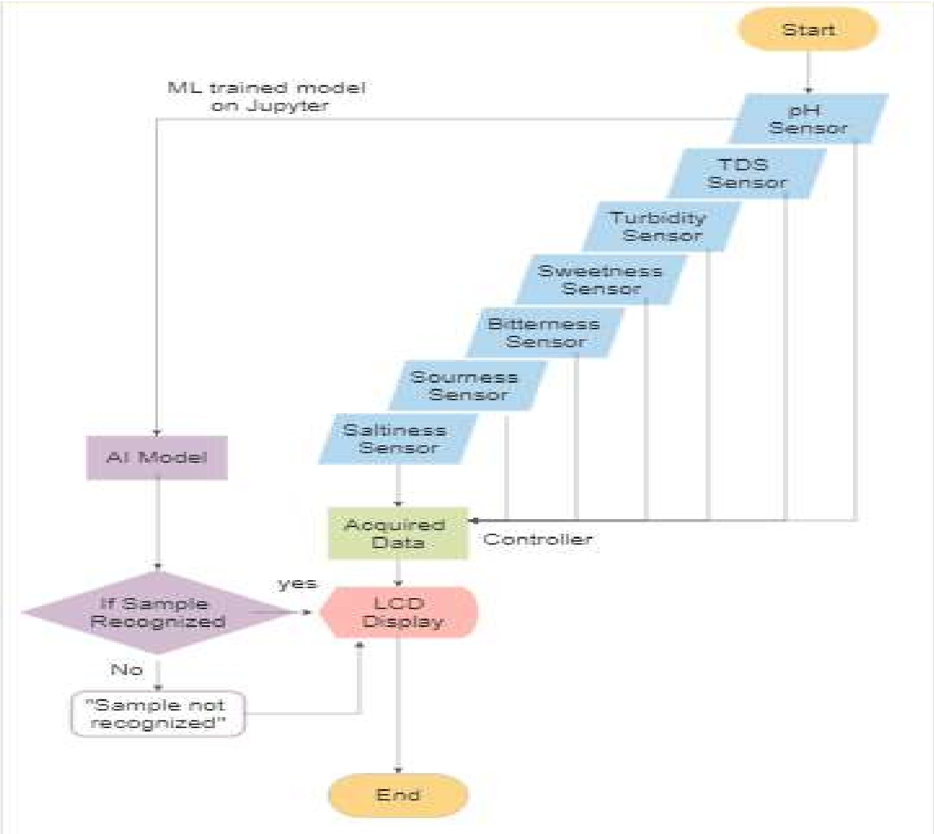


Figure 7: System Operation Methodology in form of Flow Chart

This Flowcharts represents the process or a series of steps that describe how E-Tongue Taste Sensor is working.

- Boxes in blue shows inputs.
- Green box shows storing of data.
- Red is for display.
- Purple boxes are showing the AI process.
- Yellow is for start/end.

3.2 Functionality:

1. Electrodes are solid electric conductor that carries electric current into non-metallic liquids, there are different types of electrode. There are custom built sensor which on IR sensor.
2. In this project we are using multiple sensors and electrode which will be in contact with the sample.
3. The parameter of bitterness, sweetness, sourness, saltiness, umami, TDS, Turbidity and pH will be converted into electrical form by sensors and given to our controller.
4. Now, controller will process this reading and further transfer it to the machine learning model.
5. Then, machine learning model will generate a table based on its dataset which will indicated which characteristic of taste (sweet, sour, salty, bitter and more) is present in how much quantity.
6. At the end, a chart will be generated as a result which will show information about the presence and absence of bitterness, sweetness, sourness, saltiness, umami and metal.

3.3 Block Diagram:

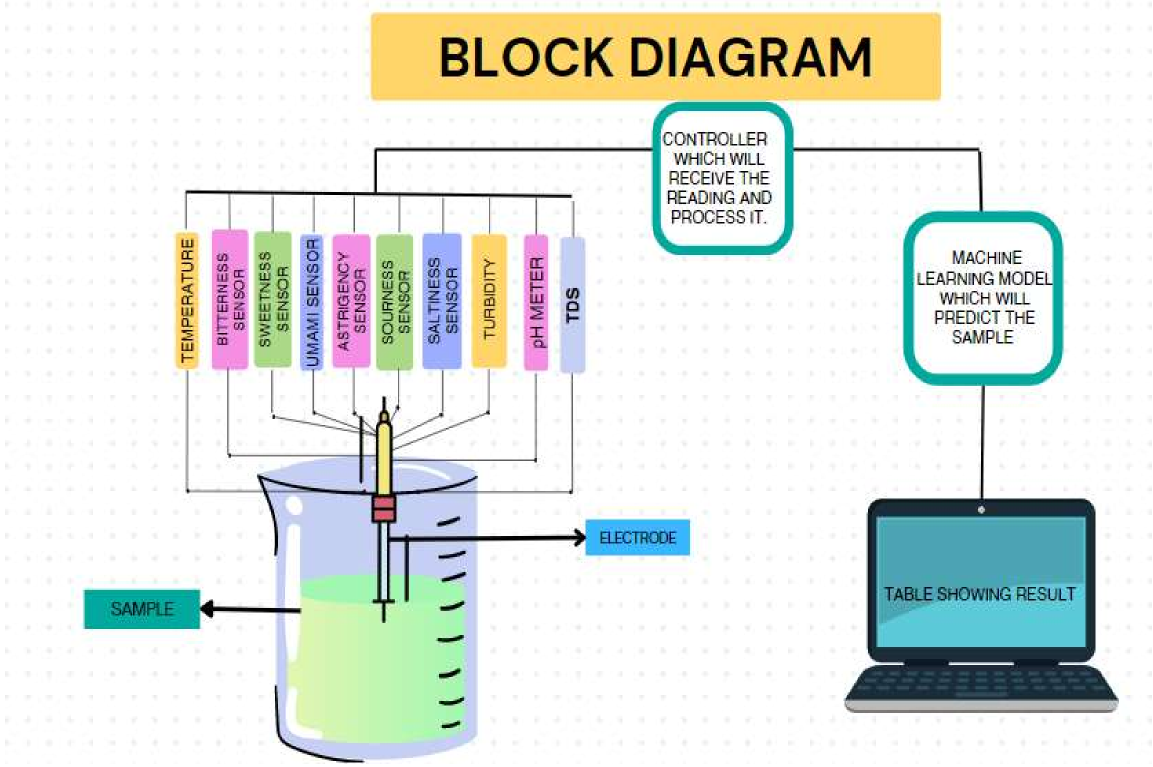


Figure 8: Block Diagram of the System

The Figure 8 shows that different electrode(sensors) will be dipped inside the sample. Further, the readings will be processed by controller. The readings will now be given to machine learning model and Quantity in percentage will be generated and shown on the screen.

3.4 Schematic Diagram:

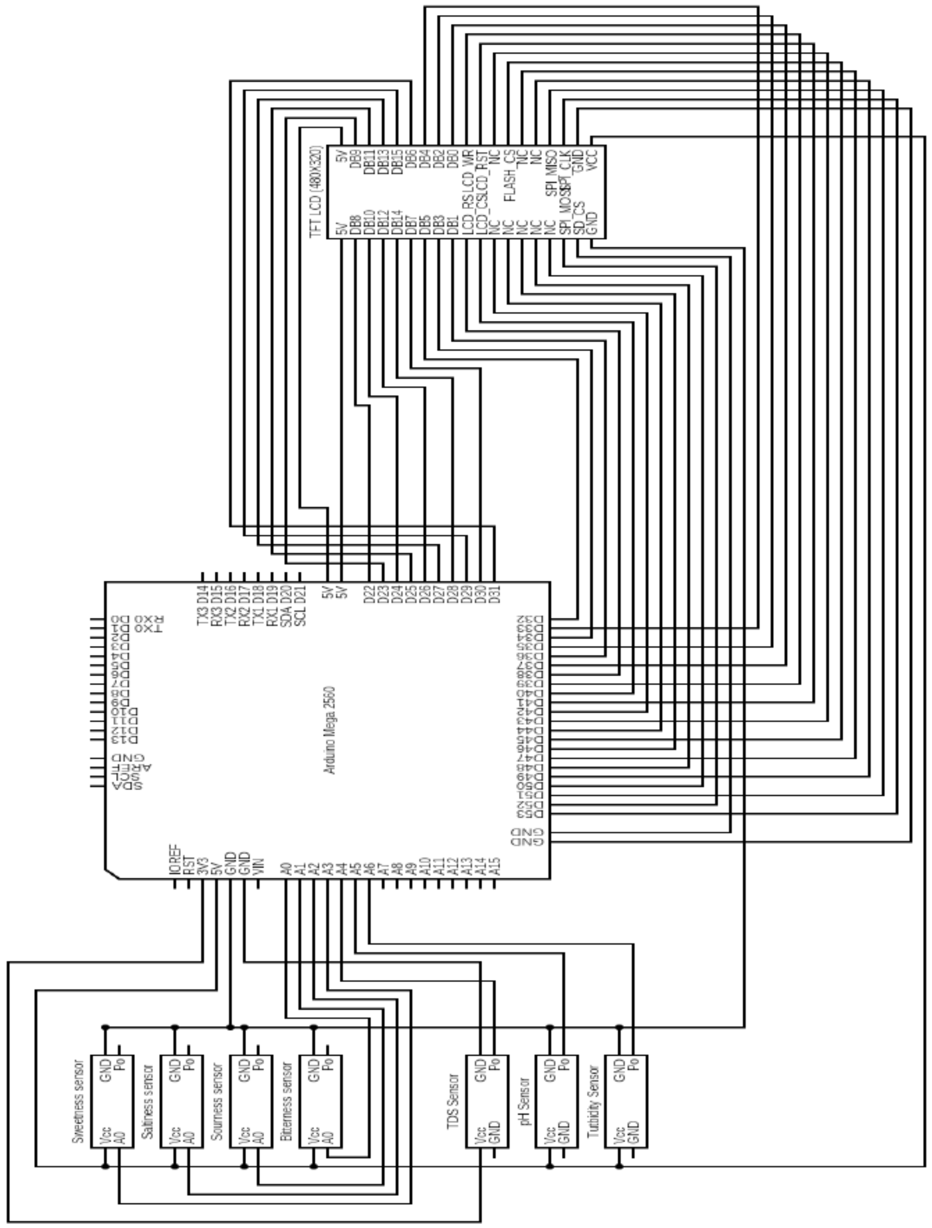


Figure 9: Schematic Diagram

The Figure 9 represents the Schematic diagram of the project where there are sensors (pH, TDS, Turbidity, Sweetness, Sourness, Saltiness and bitterness) connected to Arduino Mega along with that the TFT LCD is also connected to Arduino for display.

3.5 Hardware Components:

1) **pH Sensor:**

pH signifies the abundance of hydrogen ions within a solution. A solution characterized by a pH of 1 is considered profoundly acidic, while one boasting a pH of 14 is deemed exceedingly alkaline. pH meters find application in agricultural soil analysis, the assessment of municipal water supply purity, monitoring swimming pool conditions, and addressing environmental restoration efforts.

Figure 10: pH Sensor with its Module

2) **Turbidity Sensor:**

Turbidity is an optical characteristic that leads to the dispersion and absorption of light, as opposed to its transmission. The phenomenon of light scattering in a liquid is primarily induced by the presence of suspended particles. Elevated levels of turbidity correspond to increased quantities of dispersed light.

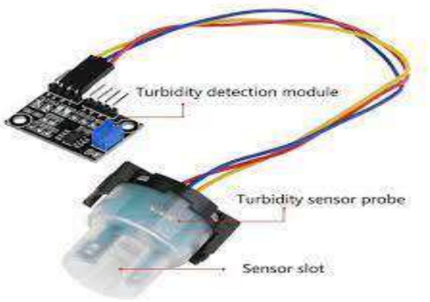


Figure 11: Turbidity Sensor with its Module

3) TDS Sensor:

The TDS sensor identifies the levels of Total Dissolved Solids (TDS) within water, serving as an indicator of its overall quality. This sensor finds utility in various water quality assessments, encompassing applications like TDS measurement, well water analysis, aquarium maintenance, hydroponic systems, and more.

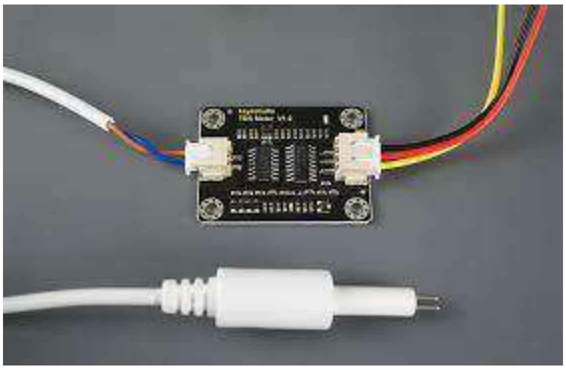


Figure 12: TDS Sensor with its Module

4) TCRT 5000 Sensor:

The TCRT5000 Infrared sensor is comprised of essential components: an IR Tx (infrared transmitter) and an IR Rx (infrared receiver). In this setup, the transmitter corresponds to a Photodiode, while the receiver takes the form of a Phototransistor. Upon receiving a voltage supply, the IR Tx promptly emits infrared signals. These signals interact with objects in their path, subsequently detected by the IR receiver. In this context, the transmitter operates akin to a transistor, with the distinction that its base terminal is stimulated by light.

Figure 13: TCRT5000 IR Sensor

Taste	Discrete voltage Per steps	Total Voltage	Current Fixed	Resistance
Bitterness	0.00488	0.00488 - 0.488	2.44E-08 - 1.39435E-06	200000 - 349985
Sourness	0.00488	0.49288 - 1.464	2.66422E-05 -1.62773E-05	18500 - 89941.296
Saltiness	0.00488	1.46888 - 3.416	1.33535E-05 -1.7979E-05	110000 - 189999.5
Sweetness	0.00488	3.42088 - 4.392	0.0001 - 0.0001	500000 - 599997.5
Umami	0.00488	4.39688 - 4.99224	8.79376E-05 -4.99228E-05	50000 - 99999.26

Table 1: Custom Built Parameters for TCRT5000

5) **Arduino Mega:**

The Arduino Mega stands as a microcontroller board known for its extensive array of digital and analog input/output pins, rendering it ideal for intricate projects necessitating multiple connections and functions. Powered by the ATmega2560 microcontroller, it incorporates 54 digital input and output pins and sixteen analog inputs. Notably, the Arduino Mega surpasses its counterparts in memory capacity, enabling it to tackle complex and resource-demanding tasks. As such, it emerges as a favored option among electronics enthusiasts, professionals, and engineers engaged in ventures that require heightened computational prowess and comprehensive hardware interfacing possibilities.

Figure 14: Arduino Mega2560 board

6) **TFT LCD 320 x 480 Pixels:**

The 3.2 Inch TFT LCD display module designed for Arduino offers a resolution of 320 x 480 pixels. The module comes with a Resistive Touch Screen Panel. LCD control is managed by SSD1289B, while the touch panel is overseen by XPT2046. This module is versatile enough to integrate with various MCUs, such as STM32, AVR, and 8051, thanks to the provided 40-pin breakout header, which also encompasses the touch panel interface.

Figure 15: 3.2 Inch TFT LCD

7) <u>Arduino UNO:</u>

The Arduino UNO stands as a well-liked microcontroller board, renowned for its straightforwardness and adaptability. Driven by the ATmega328P microcontroller, it provides 14 digital input/output pins, 6 analog inputs, and a user-friendly USB interface. Its compact dimensions and user-friendly nature render it an outstanding selection for newcomers and proficient creators alike.

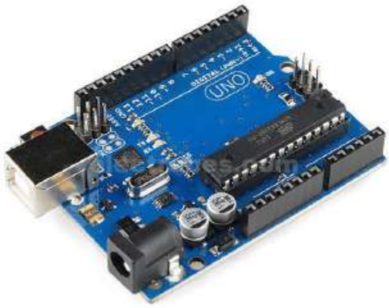


Figure 16: Arduino UNO

3.6 Project Costing:

S.No.	Component	Quantity	Estimated Cost per Piece
1	PH Sensor	2	Rs. 11,000
2	Arduino MEGA 2560	1	Rs. 4,500
3	TDS Sensor	1	Rs. 3,500
4	Turbidity Sensor	1	Rs. 3,500
5	Arduino UNO	1	Rs. 2,500
6	TFT LED Display	1	Rs. 3,800
7	Custom Built Sensor	4	Rs. 1,500
8	Miscellaneous	-	Rs. 9500
		Total	Rs. 55,300

Table 2: Total Project Costing with Components

3.7 Software of The Project:

Machine Learning:

After gathering data from various sensors using Arduino, the collected information is transmitted to our AI module for the purpose of predicting the characteristics of the given liquid sample.

Within the AI module, the initial step involves importing the dataset, which comprises of 1762 number of samples, using the powerful *pandas* library. Subsequently, the data is converted into a data frame, making it amenable to further processing. To ensure the dataset's suitability for training, we undertake a data-cleaning process to eliminate instances with low occurrence and irrelevant garbage values.

Having cleaned the data, we divide it randomly into two portions: the training data (70% of the dataset) and the test data (the remaining 30%). The training data is then fed into the machine learning classifier, specifically the Random Forest Classifier, to initiate the training process. Once the training is complete, we employ the test data to evaluate the model's performance using key metrics such as accuracy, precision, and f1-score. The results are presented in tabular and graphical formats for better visualization and understanding.

In the final phase, we deploy the trained model to process real-time data received from the Arduino. This real-time data is collected during the operation of the system and reflects the current state of the liquid sample. The prediction outcomes are then displayed.

By following this comprehensive approach, we aim to efficiently analyze and predict the properties of liquid samples, contributing to various applications in fields such as science, engineering, and industry.

Confusion matrix heat map for accuracy:

A heat map of a confusion matrix visually illustrates the content of this matrix, frequently employed to assess how well a machine learning model classifies data. The confusion matrix itself is a tabular representation that assesses a classification model's performance by contrasting its predicted labels with the actual labels for a dataset. This tool finds widespread application in supervised learning endeavors, including binary and multi-class classification tasks.

The confusion matrix typically has four components:

- True Positive (TP): This refers to the count of samples accurately classified as positive by the model.
- True Negative (TN): The refers to the count of samples accurately classified as negative by the model.
- False Positive (FP): This refers to the count of samples inaccurately classified as positive by the model (also known as Type I error).
- False Negative (FN): This refers to the number of samples inaccurately classified as negative by the model (also known as Type II error).

The confusion matrix can be visualized using a heat map, where the values in each cell are color-coded to represent the magnitude of the counts or percentages. This provides an easy-to-understand visual summary of how well the model is performing on different classes. Below we are representing the confusion matrix heat map of our trained model.

It shows that the 30% of test data plotted against predicted and actual labels. 4 out of 125 values of detergent are predicted wrong by our model. 1 out of 106 values of baking soda are predicted wrong and other than that all values are predicted right by the model. Therefore, our model's accuracy is 99%.

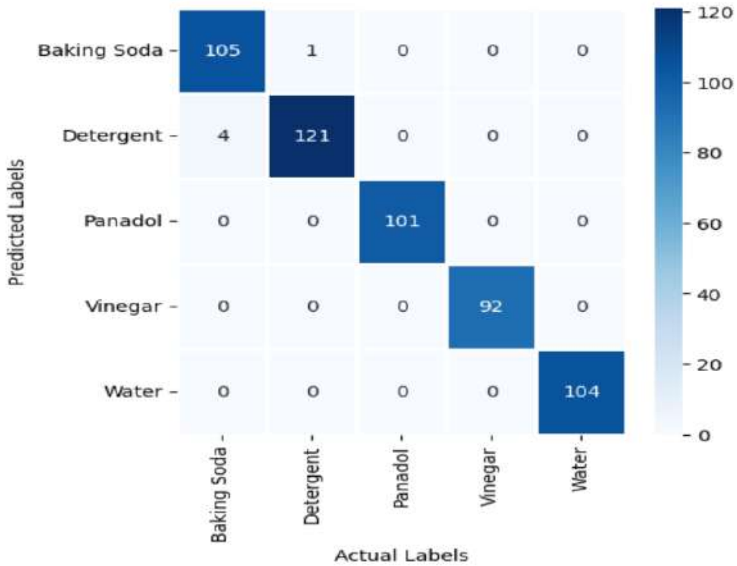


Figure 17: Confusion Matrix Heat Map

Arduino code explanation:

The Arduino code is a combination of two parts: one for interfacing with a TFT (Thin-Film Transistor) display and the other for reading various sensors (TDS sensor, pH sensor, turbidity sensor, and IR sensor) and displaying their values on the TFT display.

1) TFT Display Part: This part of the code initializes and interacts with the TFT display using the "TFT_HX8357" library. It sets up the display, clears the screen, and prints pH and TDS values on the TFT screen. The color and positioning of the text are also specified.

2) Sensor Reading and Display Part: This part of the code is responsible for reading values from different sensors and displaying their readings on the serial monitor and the TFT display.

The sensors used are as follows:

- TDS sensor: It measures the Total Dissolved Solids (TDS) in water and is connected to pin A5.
- pH Sensor: It measures the pH level of the liquid and is connected to pin A6.
- Turbidity Sensor: It measures the turbidity of the liquid (how clear or cloudy it is) and is connected to pin A4.
- IR Sensor: This sensor seems to be used for determining taste sensations (bitter, sour, salty, sweet, umami) based on analog readings from multiple analog input pins (A0 to A3).
- The code then calculates and maps the values from the IR sensor to percentages of each taste sensation and displays the corresponding values on the serial monitor and the TFT display.

The loop function includes the following steps:

- Reading analog values from the IR sensor (taste sensor) and mapping them to percentage values for each taste sensation (bitter, sour, salty, sweet, umami).
- Reading the pH level from the pH sensor and performing calibration.
- Reading the TDS value from the TDS sensor.
- Reading the turbidity state from the turbidity sensor.

Displaying the values and taste sensations on the serial monitor and TFT display.

Please note that the actual calculations and mappings for taste sensations are done based on the analog readings from the IR sensor and might require calibration for accurate results. The sensor connections and pin assignments may vary based on the hardware setup, so make sure to check your connections and library documentation accordingly.

3.8 Project Design:

The Project hardware was designed such that the working of the system could easily observed. In this device sensors were placed on the acrylic disk and that disk is being dipped in the bowl of sample. The screen is visible to display the result and the wires and controllers are placed behind the screen. All these Details can be observed in the Figure 18.

Figure 18: Project Completed Hardware

CHAPTER 4

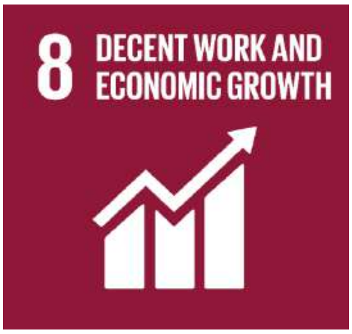
ENGINEER AND SOCIETY

The relationship between engineers and society is a dynamic and symbiotic one, with engineers being integral to the advancement and well-being of societies worldwide. Engineers are the architects of progress, responsible for designing, creating, and maintaining the infrastructure, technologies, and systems that shape our modern world. This intersection between engineering and society is where innovation, problem-solving, and societal impact converge.

Engineers play a pivotal role in addressing some of the most pressing challenges of our time, from designing sustainable energy solutions to developing life-saving medical devices, and from creating efficient transportation networks to ensuring clean water and sanitation. Their work has the power to enhance the quality of life for individuals and communities while also promoting economic growth and environmental sustainability.

Moreover, engineers are not solely technical experts; they are also ethical stewards of their creations. As such, they must consider the social, ethical, and environmental implications of their projects. The decisions made by engineers can have far-reaching consequences, influencing safety, equity, and the overall well-being of society. Therefore, a deep understanding of the societal context in which they operate is essential for engineers to make responsible and informed choices.

4.1 UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS

	• **Goal no - 03 (Good Health and Well-Being)** • Ensure healthy lives and promote well-being for all at all ages • Access to good health and well-being is every individual right and this could be achieved by E-tongue taste sensor as it can also detect spoilage of food. • E-tongue taste sensor can help to reduce the use of toxic compounds in the edibles items.
	• **Goal no – 6 (Clean water and sanitation)** • Ensure availability and sustainable management of water and sanitation for all. • In 2030, 1.6 billion people will lack safety of drinkable water. • For at least 3 billion people the quality of the water they depend on is unmonitored. • Our device can help to monitor the quality of water.
	• **Goal no - 08 (Decent work and economic growth)** • Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all. • By developing E-tongue taste sensor we can use science and technology for sustainable development. • E-tongue taste sensor device can help local industries to grow and this can lead to economic growth
	• **Goal no - 09 (Industry, Innovation and Infrastructure)** • Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. • Small scale industries have less access for financial support. • E-tongue taste sensor device constructed in Pakistan can reduce its cost and help in improving quality of products of pharma and food companies.

	• **Goal no - 12 (Responsible consumption and production)** • Ensure sustainable consumption and production patterns. • 13.3% of the world's food is lost after harvesting and before reaching the wholesale. • 17% of total food is wasted at the user level. • These numbers could be reduced by usage of E-tongue taste sensor because manufacturing of flawed sample can be reduced.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 System Analysis Parameters:

The system can analyze major taste parameters of the sample:

Parameter	Range	Unit	Symbol
Sweetness	0-100	Percentage	%
Sourness	0-100	Percentage	%
Saltiness	0-100	Percentage	%
Bitterness	0-100	Percentage	%
pH	1-14	-	-
TDS	0-500	Parts per Million	ppm
Turbidity	0-1000	Nephelometric Turbidity Units	NTUs

Table 3 Major Parameters Analyzed by the System

The sample readings can be referenced in Figure.

Figure 19: Sample Reading Reference

5.2 System Specifications

The sensors are turned on when controller is given power supply and when dipped in the solution the result in form of readings is shown on the LCD screen. The reading from the pH sensor goes to the machine learning model through controller and it predicts the sample type. This result is shown on the display.

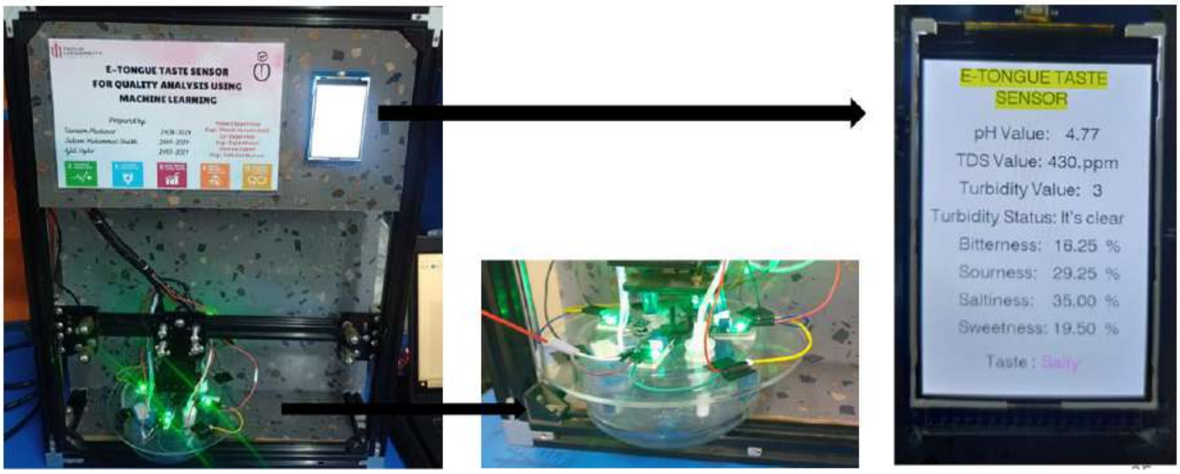


Figure 20: Project Image

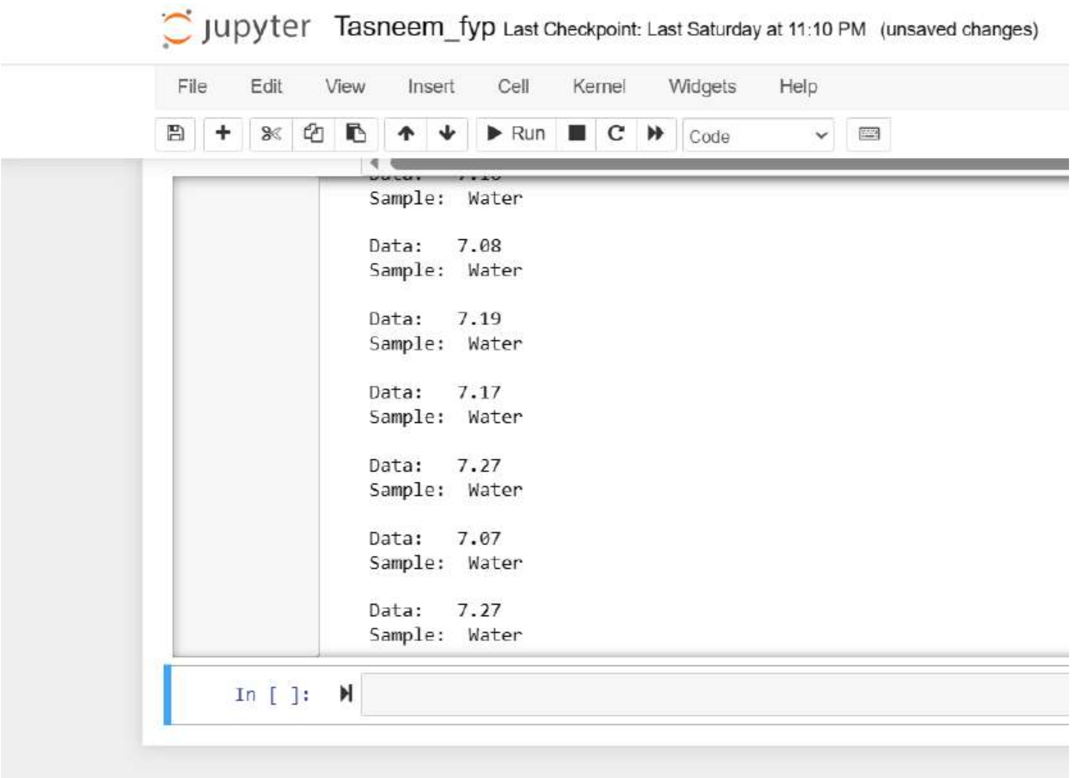


Figure 21: Machine Learning Sample Results

CHAPTER 6

CONCLUSION AND FUTURE WORK

6.1 Conclusion

In conclusion, The E-tongue taste device has demonstrated remarkable promise in enhancing food sample quality assessment, effectively emulating the human sense of taste. This cutting-edge technology excels in detecting and analyzing diverse taste attributes, including sweetness, bitterness, saltiness, sourness, and umami. Moreover, it enables objective evaluations of food quality, enabling early detection of contaminants. By incorporating additional parameters like pH, turbidity, and TDS measurements, it provides a comprehensive view of taste and sample quality.

The electronic tongue taste machine offers several notable advantages. Firstly, it eliminates subjective human bias in taste assessments, ensuring consistent and reliable results. Secondly, it accelerates the evaluation process, facilitating quicker decisions in food production and quality control. Thirdly, its ability to assess multiple taste attributes simultaneously enhances its versatility and usefulness in various industries, including food and beverage, pharmaceuticals, and environmental monitoring.

6.2 Future Work

Many modifications and additions can be made in the existing system which would fall under possible future work, such as:

E-tongue taste sensors can be utilized in the **Pharmaceutical industry** for:

1. Quality Control and Assurance
2. Formulation Development
3. Taste-Masking Evaluation (improvement of taste)
4. Stability Testing
5. Bioavailability Assessment

6. Drug Interaction Studies
7. Quality Evaluation of Excipients
8. Personalized Medicine

E-tongue taste sensors can be used in **Food companies** for:

1. Quality Control
2. Taste Optimization
3. Flavor Enhancement
4. Shelf Life and Stability Testing
5. Authentication and Quality Verification
6. Sensory Evaluation
7. Product Differentiation
8. Personalized Nutrition
9. Research and development

E-tongue taste sensors can be utilized in the **Medical field** for:

1. Assessment of Oral Disintegration
2. Drug Delivery Systems
3. Diagnosis of Diseases
4. Taste Assessment in Geriatric and Pediatric Patients
5. Evaluation of Oral Care Products
6. Detection of Bacterial Infections
7. Assessment of Artificial Sweeteners
8. Nutritional Assessment

E-tongue taste sensors can be used in **Agriculture** for:

1. Crop Quality Assessment
2. Soil Analysis
3. Irrigation Management
4. Pesticide Residue Detection
5. Plant Disease Detection
6. Crop Breeding and Selection
7. Post-Harvest Quality Control
8. Plant Stress Monitoring
9. Taste-Based Sorting and Grading
10. Evaluation of Agricultural Products

E-tongue taste sensors can be used for **Water purification**:

1. Water Quality Evaluation
2. Monitoring Purification Processes
3. Taste Improvement
4. Detecting Residual Chemicals
5. Water Source Assessment
6. Real-time Monitoring
7. Consumer Acceptance

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APPENDIX

A. Complete Arduino Programming Code:

```
// TFT code
#include <TFT_HX8357.h> // Hardware-specific library

TFT_HX8357 tft = TFT_HX8357();       // Invoke custom library

unsigned long targetTime = 0;
byte red = 31;
byte green = 0;
byte blue = 0;
byte state = 0;
unsigned int colour = red << 11; // Colour order is RGB 5+6+5 bits each

// TFT code end

// Final code
#include <Wire.h>
#include <EEPROM.h>
#include "GravityTDS.h"

#define TdsSensorPin A5 // tds input
int sensorPin = A4; // turbidity input

GravityTDS gravityTds;

float temperature = 25;
float tdsValue = 0;


float calibration_value = 21.34 + 3.4 ;
int phval = 0;
unsigned long int avgval;
int buffer_arr[10],temp;


// Define the analog input pin for the IR sensor
const int analogPin = A0;
const int analogPin1 = A1;
const int analogPin2 = A2;
const int analogPin3 = A3;
float per;
float a,b,c,d,e=0;

// Final code end

void setup(void) {
// TFT code
  tft.init();
  tft.setRotation(2);
  tft.fillScreen(TFT_BLACK);

  targetTime = millis() + 1000;
```

```
// TFT code end

// Final code
   Serial.begin(9600);
   gravityTds.setPin(TdsSensorPin);
   gravityTds.setAref(5.0);  //reference voltage on ADC, default 5.0V on Arduino UNO
   gravityTds.setAdcRange(1024);  //1024 for 10bit ADC;4096 for 12bit ADC
   gravityTds.begin();  //initialization

//Final code end
}


void loop()
{

  // Read the analog value from the IR sensor
  int analogValue = analogRead(analogPin);
  int analogValue1 = analogRead(analogPin1);
  int analogValue2 = analogRead(analogPin2);
  int analogValue3 = analogRead(analogPin3);

  float bitter = map(analogValue, 0, 100 , 0, 100);
  float sour = map(analogValue1, 101, 300 , 0, 100); //Tasneem changed
  float salt = map(analogValue2, 301, 700 , 0, 100); //Tasneem changed
  float sweet = map(analogValue3, 701, 900 , 0, 100);

    for(int i=0;i<10;i++)
 {
 buffer_arr[i]=analogRead(A6);  // ph input
 delay(30);
 }
 for(int i=0;i<9;i++)
 {
 for(int j=i+1;j<10;j++)
 {
 if(buffer_arr[i]>buffer_arr[j])
 {
 temp=buffer_arr[i];
 buffer_arr[i]=buffer_arr[j];
 buffer_arr[j]=temp;
 }
 }
 }
 avgval=0;
 for(int i=2;i<8;i++)
 avgval+=buffer_arr[i];
 float volt=(float)avgval*5.0/1024/6;
 float ph_act = -5.0 * volt + calibration_value;

   gravityTds.setTemperature(temperature);  // set the temperature and execute temperature compensation
   gravityTds.update();  //sample and calculate
   tdsValue = gravityTds.getTdsValue();  // then get the value

    int sensorValue = analogRead(sensorPin);
  int turbidity = map(sensorValue, 0, 750, 100, 0);
  delay(100);
```

```
  Serial.print("pH Val:");
  Serial.println(ph_act);
  tft.setCursor(50, 10, 4.9);    // Set cursor to x = 70, y = 175
  tft.setTextColor(TFT_WHITE, TFT_BLUE);  // Set text colour to white and background to black
  tft.println("E-TONGUE TASTE");
   tft.setCursor(100, 40, 4.9);
  tft.println("SENSOR");
  tft.setCursor(70, 90, 4.9);    // Set cursor to x = 70, y = 175
  tft.setTextColor(TFT_WHITE, TFT_BLACK);  // Set text colour to white and background to black
  tft.println("pH Value:");
  tft.setCursor(200, 90, 4.9);
  tft.println(ph_act);


Serial.print("TDS Reading:  ");
Serial.print(tdsValue,0);
Serial.println("ppm");
tft.setCursor(45, 130, 4.9);    // Set cursor to x = 70, y = 175
tft.setTextColor(TFT_WHITE, TFT_BLACK);  // Set text colour to white and background to black
tft.println("TDS Value: ");
tft.setCursor(175, 130, 4.9);
tft.println(tdsValue);
tft.setCursor(225, 130, 4.9);
tft.println("ppm");


 Serial.print("turbidity Reading: ");
 Serial.println(turbidity);
tft.setCursor(50, 170, 4.9);    // Set cursor to x = 70, y = 175
tft.setTextColor(TFT_WHITE, TFT_BLACK);  // Set text colour to white and background to black
tft.println("Turbidity Value: ");
tft.setCursor(240, 170, 4.9);
tft.println(turbidity);

 delay(100);


 if (turbidity < 20) {

   Serial.print("Turbidity Status :  ");
   Serial.println(" its CLEAR ");
   delay(500);
tft.setCursor(10, 210, 4.9);
tft.setTextColor(TFT_WHITE, TFT_BLACK);  // Set text colour to white and background to black
tft.println("Turbidity Status: It's clear ");
 }
 if ((turbidity > 20) && (turbidity < 50)) {


   Serial.print("Turbidity Status :  ");
   Serial.println(" its CLOUDY ");
   delay(500);
tft.setCursor(10, 210, 4.9);
tft.setTextColor(TFT_WHITE, TFT_BLACK);  // Set text colour to white and background to black
tft.println("Turbidity Status: It's cloudy ");
 }
```

```
if (turbidity > 50) {


   Serial.print("Turbidity Status :  ");
   Serial.println(" its DIRTY ");
   delay(500);
 tft.setCursor(10, 210, 4.9);
 tft.setTextColor(TFT_WHITE, TFT_BLACK);  // Set text colour to white and background to black
 tft.println("Turbidity Status: It's dirty ");
  }

// Map the analog value to taste sensations
  String taste;
  if (bitter >= 0 && bitter <= 100  ) {
   taste = "Bitter";

     a = bitter * 1;
     b = (100 - a) * 0.45;
     c = (100 - a) * 0.30;
     d = (100 - a) * 0.25;


     Serial.print("Percentage of Bitterness : ");
     Serial.println(a);
     Serial.print("Percentage of Sourness : ");
     Serial.println(b);
     Serial.print("Percentage of Saltness : ");
     Serial.println(c);
     Serial.print("Percentage of Sweetness : ");
     Serial.println(d);

       tft.setCursor(50, 250, 4.9);    // Set cursor to x = 70, y = 175
   tft.setTextColor(TFT_WHITE, TFT_BLACK);  // Set text colour to white and background to black
   tft.println("Bitterness:");
   tft.setCursor(185, 250, 4.9);
   tft.println(a);
   tft.setCursor(260, 250, 4.9);
   tft.println("%");
       tft.setCursor(50, 290, 4.9);    // Set cursor to x = 70, y = 175
   tft.setTextColor(TFT_WHITE, TFT_BLACK);
   tft.println("Sourness:");
   tft.setCursor(185, 290, 4.9);
   tft.println(b);
   tft.setCursor(260, 290, 4.9);
   tft.println("%");
       tft.setCursor(50, 330, 4.9);    // Set cursor to x = 70, y = 175
   tft.setTextColor(TFT_WHITE, TFT_BLACK);
   tft.println("Saltiness:");
   tft.setCursor(185, 330, 4.9);
   tft.println(c);
   tft.setCursor(260, 330, 4.9);
   tft.println("%");
         tft.setCursor(50, 370, 4.9);    // Set cursor to x = 70, y = 175
   tft.setTextColor(TFT_WHITE, TFT_BLACK);
   tft.println("Sweetness:");
   tft.setCursor(185, 370, 4.9);
   tft.println(d);
```

```
tft.setCursor(260, 370, 4.9);
  tft.println("%");


 } else if (sour >= 0 && sour <= 100) {//Tasneem changed
  taste = "Sour";

   b = sour * 1;
   a = (100 - b) * 0.45;//Tasneem changed
   c = (100 - b) * 0.30;//Tasneem changed
   d = (100 - b) * 0.25;//Tasneem changed
   //Serial.println(analogValue1);
   Serial.print("Percentage of Bitterness : ");
   Serial.println(a);
   Serial.print("Percentage of Sourness : ");
   Serial.println(b);
   Serial.print("Percentage of Saltness : ");
   Serial.println(c);
   Serial.print("Percentage of Sweetness : ");
   Serial.println(d);

    tft.setCursor(50, 250, 4.9);    // Set cursor to x = 70, y = 175
  tft.setTextColor(TFT_WHITE, TFT_BLACK);  // Set text colour to white and background to black
  tft.println("Bitterness:");
  tft.setCursor(185, 250, 4.9);
  tft.println(a);
  tft.setCursor(260, 250, 4.9);
  tft.println("%");
    tft.setCursor(50, 290, 4.9);    // Set cursor to x = 70, y = 175
  tft.setTextColor(TFT_WHITE, TFT_BLACK);
  tft.println("Sourness:");
  tft.setCursor(185, 290, 4.9);
  tft.println(b);
  tft.setCursor(260, 290, 4.9);
  tft.println("%");
    tft.setCursor(50, 330, 4.9);    // Set cursor to x = 70, y = 175
  tft.setTextColor(TFT_WHITE, TFT_BLACK);
  tft.println("Saltiness:");
  tft.setCursor(185, 330, 4.9);
  tft.println(c);
  tft.setCursor(260, 330, 4.9);
  tft.println("%");
      tft.setCursor(50, 370, 4.9);    // Set cursor to x = 70, y = 175
  tft.setTextColor(TFT_WHITE, TFT_BLACK);
  tft.println("Sweetness:");
  tft.setCursor(185, 370, 4.9);
  tft.println(d);
  tft.setCursor(260, 370, 4.9);
  tft.println("%");


 } else if (salt >= 0 && salt <= 100 ) {//Tasneem changed
  taste = "Salty";

   c = salt * 4 ;
   a = (100 - c) * 0.40;//Tasneem changed
   b = (100 - c) * 0.35;//Tasneem changed
```

```
d = (100 - c) * 0.25;//Tasneem changed
   //Serial.println(analogValue2);
   Serial.print("Percentage of Bitterness : ");
   Serial.println(a);
   Serial.print("Percentage of Sourness : ");
   Serial.println(b);
   Serial.print("Percentage of Saltness : ");
   Serial.println(c);
   Serial.print("Percentage of Sweetness : ");
   Serial.println(d);

    tft.setCursor(50, 250, 4.9);    // Set cursor to x = 70, y = 175
  tft.setTextColor(TFT_WHITE, TFT_BLACK);  // Set text colour to white and background to black
  tft.println("Bitterness:");
  tft.setCursor(185, 250, 4.9);
  tft.println(a);
  tft.setCursor(260, 250, 4.9);
  tft.println("%");
    tft.setCursor(50, 290, 4.9);    // Set cursor to x = 70, y = 175
  tft.setTextColor(TFT_WHITE, TFT_BLACK);
  tft.println("Sourness:");
  tft.setCursor(185, 290, 4.9);
  tft.println(b);
  tft.setCursor(260, 290, 4.9);
  tft.println("%");
    tft.setCursor(50, 330, 4.9);    // Set cursor to x = 70, y = 175
  tft.setTextColor(TFT_WHITE, TFT_BLACK);
  tft.println("Saltiness:");
  tft.setCursor(185, 330, 4.9);
  tft.println(c);
  tft.setCursor(260, 330, 4.9);
  tft.println("%");
      tft.setCursor(50, 370, 4.9);    // Set cursor to x = 70, y = 175
  tft.setTextColor(TFT_WHITE, TFT_BLACK);
  tft.println("Sweetness:");
  tft.setCursor(185, 370, 4.9);
  tft.println(d);
  tft.setCursor(260, 370, 4.9);
  tft.println("%");

 } else if (sweet >= 0 && sweet <= 100 ) {
  taste = "Sweet";

   d = sweet * 1;
   a = (100 - d) * 0.25;
   b = (100 - d) * 0.30;
   c = (100 - d) * 0.45;

   Serial.print("Percentage of Bitterness : ");
   Serial.println(a);
   Serial.print("Percentage of Sourness : ");
   Serial.println(b);
   Serial.print("Percentage of Saltness : ");
   Serial.println(c);
   Serial.print("Percentage of Sweetness : ");
   Serial.println(d);
```

```
 tft.setCursor(50, 250, 4.9);    // Set cursor to x = 70, y = 175
   tft.setTextColor(TFT_WHITE, TFT_BLACK);  // Set text colour to white and background to black
   tft.println("Bitterness:");
   tft.setCursor(185, 250, 4.9);
   tft.println(a);
   tft.setCursor(260, 250, 4.9);
   tft.println("%");
      tft.setCursor(50, 290, 4.9);    // Set cursor to x = 70, y = 175
   tft.setTextColor(TFT_WHITE, TFT_BLACK);
   tft.println("Sourness:");
   tft.setCursor(185, 290, 4.9);
   tft.println(b);
   tft.setCursor(260, 290, 4.9);
   tft.println("%");
      tft.setCursor(50, 330, 4.9);    // Set cursor to x = 70, y = 175
   tft.setTextColor(TFT_WHITE, TFT_BLACK);
   tft.println("Saltiness:");
   tft.setCursor(185, 330, 4.9);
   tft.println(c);
   tft.setCursor(260, 330, 4.9);
   tft.println("%");
         tft.setCursor(50, 370, 4.9);    // Set cursor to x = 70, y = 175
   tft.setTextColor(TFT_WHITE, TFT_BLACK);
   tft.println("Sweetness:");
   tft.setCursor(185, 370, 4.9);
   tft.println(d);
   tft.setCursor(260, 370, 4.9);
   tft.println("%");

  } else {
   taste = "Umami";
      //tft.setTextColor(TFT_WHITE, TFT_BLACK);
   //tft.setCursor(70, 350, 4.9);
   //tft.println("Umami");
  }

   Serial.println("");
  // Print the detected taste through the serial monitor
  Serial.print("Taste: ");
 Serial.println(taste);
 Serial.println("");
    tft.setTextColor(TFT_WHITE, TFT_BLACK);
   tft.setCursor(90, 420, 4.9);
   tft.println("Taste : ");
   tft.setTextColor(TFT_GREEN, TFT_BLACK);
   tft.setCursor(170, 420, 4.9);
   tft.println(taste);

  delay(2000); // Delay for better readability, adjust as needed
delay(5000);

   Serial.println("  ");
   Serial.println("  ");
   Serial.println("  ");
   Serial.println("  ");

}
```

B. Complete Machine Learning Code:

```
#pd is used for pandas
import pandas as pd
#giving the path of the data set,
data=pd.read_csv("C:/Users/Dell/Documents/semester #8/FYP II/pH dataset.csv",header=[1])
data.head() #default value is 5 rows
#we dropped the word ready from the dataset
data = data.drop(data[data['pH'] == 'Ready'].index)
#displaying the shape of the dataset
data.shape
#converting data type of pH from string to float
Ph=[]
for i in data['pH']:
  value=float(i)
  Ph.append(value)
# Saving it in the column in Dataframe
data['pH']=Ph
#making dataframe of baking soda
df_baking_soda=data[data['Label']=='Baking Soda']
#displaying the label counts
data.value_counts('Label')
# dropping the insufficient data
data = data.drop(data[data['Label'] == 'vinegar'].index)
##displaying the label counts
data.value_counts('Label')
# Spliting the data in test and train with a ratio for 70:30. Where 70% goes in training and 30% goes for testing
from sklearn.model_selection import train_test_split
y,levels = pd.factorize(data['Label'])
x_train1, x_test1, y_train, y_test = train_test_split(data['pH'],y,test_size=0.30,stratify=data['Label'])
print(levels)
# Converting to frames
x_train=x_train1.to_frame()
x_test=x_test1.to_frame()
#y_test=y_test.to_frame()
#y_train=y_train.to_frame()
# Training model
from sklearn.ensemble import RandomForestClassifier
modelR = RandomForestClassifier(24)
modelR.fit(x_train,y_train)
# Running predictions on test data
predict=modelR.predict(x_test)
# Displaying confusion matrix
from sklearn.metrics import confusion_matrix,classification_report
import matplotlib.pyplot as plt
import seaborn as sns
#y_pred_class = y_pred_pos > threshold
#confusion_matrix = confusion_matrix(y_test, predict)
cf_matrix = pd.crosstab(levels[y_test],levels[predict])
fig, ax = plt.subplots(figsize=(5,5))
s = sns.heatmap(cf_matrix, linewidths=1, annot=True, ax=ax, fmt='g', cmap='Blues')
s.set(xlabel='Actual Labels', ylabel='Predicted Labels')
# Displaying Classification report
print(classification_report(y_test, predict, target_names=levels))
```

```
import serial
import re
import time
import warnings

# Define the serial port and baud rate. Make sure to use the same baud rate as in your Arduino sketch (9600 in this example).
ser = serial.Serial('COM4', 9600)  # Replace 'COM4' with the appropriate port name on your system

try:
    while True:
        # Read data from the serial port
        data = ser.readline().decode('utf-8').rstrip()
        print("\nData: ", data)

        # Regular expression pattern to find float values
        float_pattern = r"[-+]?\d*\.\d+|\d+"

        # Use re.findall to find all float values in the line
        float_values = re.findall(float_pattern, data)

        # Convert the extracted values to float
        float_values = [float(value) for value in float_values]
       # print("float values: ", float_values)

        if float_values:
            new = pd.DataFrame(float_values)
        #    print("Final value:", new)

            warnings.filterwarnings("ignore", message="X does not have valid feature names, but RandomForestClassifier was fitted
with feature names")

            # Assuming you have defined and trained 'modelR' for prediction
            predict = modelR.predict(new)
            print("Sample: ", levels[predict][0])

        # Add a time delay of 1 second before the next iteration
        time.sleep(5)

except KeyboardInterrupt:
    # Close the serial port when the loop is terminated
    ser.close()
```

C. Dataset:

(https://drive.google.com/drive/folders/1u-FLXalZ9XtPj9uxkoxuFKkIyYU-Sff8)

D. Datasheets:

Grove - PH Sensor Kit (E-201C-Blue)

PRODUCT DETAILS

Feature

- Widely used in chemical industry, pharmaceutical industry, dye industry, and scientific research
- Support with both Arduino and Rasberry Pi
- Compact size for easy deployment and cost-effective
- Resolution: at most ±0.15PH (STP)
- Probe replaceable

Description

Are you trying to find an easy to use and cost-effect PH sensor/meter? Do you want to use a PH sensor/meter with Arduino or Raspberry Pi? Well, this new Grove - PH Sensor will meet all your needs. The PH sensor measures the hydrogen-ion activity in water-based solutions, we usually use it to measure the PH of a liquid. It is widely used in the chemical industry, the pharmaceutical industry, the dye industry, and scientific research where acidity and alkalinity testing is required. The drive board in this kit support both 3.3V and 5V system. And with the stander BNC probe interface and Grove connector, it is very convenient to work with Arduino and Raspberry Pi.

Note

This product is non-RoHS certified.

Specification

Items	Values
Operating voltage	3.3V/5V
Range	0-14PH
Resolution	±0.15PH（STP）
Response time	＜1min
Probe Interface	BNC
Measure temperature	0-60℃
Internal resistance	≤250MΩ（25℃）
Alkali error	0.2PH（1mol/L）Na+，PH14）（25℃）

Cautions

- Before being measured, the electrode must be calibrated with a standard buffer solution of known PH value. In order to obtain more accurate results, the known PH value should be reliable, and closer to the measured one.
- When the measurement is completed, the electrode protective sleeve should be put on. A small amount of 3.3mol / L potassium chloride solution should be placed in the protective sleeve to keep the electrode bulb wet.
- The leading end of the electrode must be kept clean and dry to absolutely prevent short circuits at both ends of the output, otherwise it will lead to inaccurate or invalid measurement results.
- After long-term use of the electrode, if you find that the gradient is slightly inaccurate, you can soak the lower end of the electrode in 4% HF (hydrofluoric acid) for 3-5 seconds, wash it with distilled water, and then soak in potassium chloride solution to make it new.

Part list

Items	Quantity
PH prober	1
Grove cable	1
Driver board	1
Saturated sodium chloride solution	1

What is Grove?

Grove makes it easier to connect, experiment, and simplify the prototyping process. No jumpers or soldering required. We have developed more than 300 Grove modules, covering a wide range of applications that can fulfil a variety of needs. Not only are these open hardware, but we also have open-source software.

Note

For all Grove users (especially beginners), we provide you with the guidance of operation. Please read the instructions through the official website before your using the product.

ECCN/HTS

HSCODE	9031809090
UPC	

Turbidity sensor SKU: SEN0189

Contents

Introduction

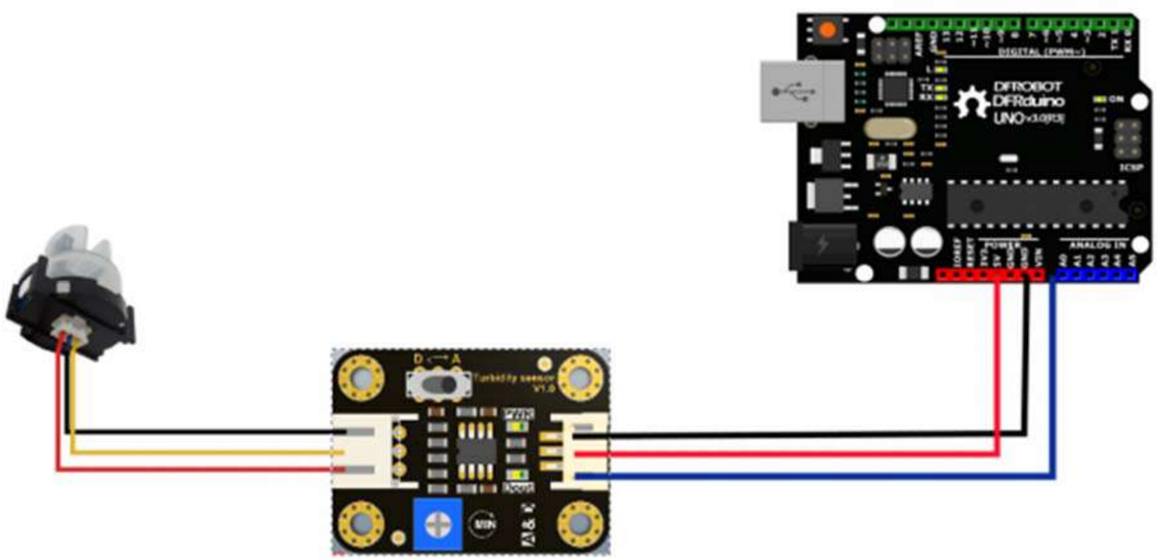
The turbidity sensor detects water quality by measuring the levels of turbidity. It uses light to detect suspended particles in water by measuring the light transmittance and scattering rate, which changes with the amount of total suspended solids (TSS) in water. As the TTS increases, the liquid turbidity level increases.
Turbidity sensors are used to measure water quality in rivers and streams, wastewater and effluent measurements, control instrumentation for settling ponds, sediment transport research and laboratory measurements.
This sensor provides analog and digital signal output modes. The threshold is adjustable when in digital signal mode. You can select the mode according to your MCU.

Note: The top of probe is not waterproof.

Specification

- Operating Voltage: 5V DC
- Operating Current: 40mA (MAX)
- Response Time : <500ms
- Insulation Resistance: 100M (Min)
- Output Method:
  Analog output: 0-4.5V
  Digital Output: High/Low level signal (you can adjust the threshold value by adjusting the potentiometer)
- Operating Temperature: 5℃~90℃
- Storage Temperature: -10℃~90℃
- Weight: 30g
- Adapter Dimensions: 38mm*28mm*10mm/1.5inches *1.1inches*0.4inches

Connection Diagram



Interface Description:

---

1. "D/A" Output Signal Switch
1. "A": Analog Signal Output, the output value will decrease when in liquids with a high turbidity
2. "D": Digital Signal Output, high and low levels, which can be adjusted by the threshold potentiometer
2. Threshold Potentiometer: you can change the trigger condition by adjusting the threshold potentiometer in digital signal mode.

Examples

Here are two examples:
Example 1 uses Analog output mode
Example 2 uses Digital output mode

Example 1

```
void setup() {
  Serial.begin(9600); //Baud rate: 9600
}
void loop() {
  int sensorValue = analogRead(A0);// read the input on analog pin 0:
  float voltage = sensorValue * (5.0 / 1024.0); // Convert the analog read
ing (which goes from 0 - 1023) to a voltage (0 - 5V):
  Serial.println(voltage); // print out the value you read:
  delay(500);
}
```

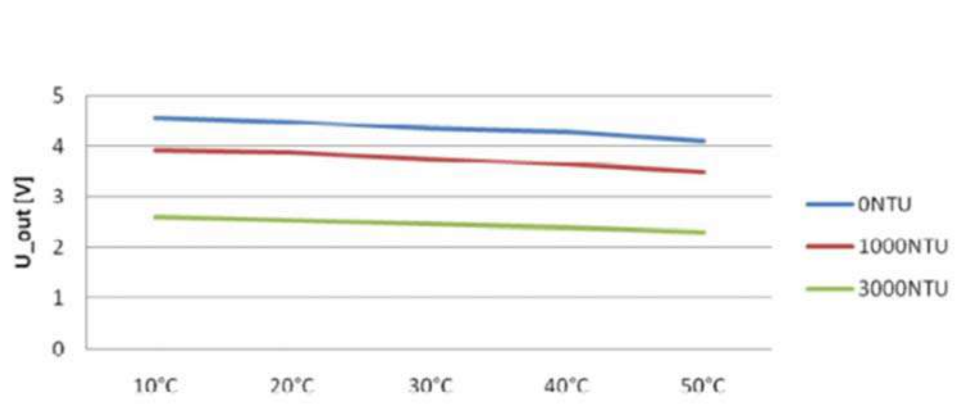
Example 2

```
int ledPin = 13;                // Connect an LED on pin 13, or use the on
board one
int sensor_in = 2;                 // Connect turbidity sensor to Digital
Pin 2
```

```
void setup(){
  pinMode(ledPin, OUTPUT);      // Set ledPin to output mode
  pinMode(sensor_in, INPUT);       //Set the turbidity sensor pin to input
mode
}

void loop(){
   if(digitalRead(sensor_in)==LOW){       //read sensor signal
        digitalWrite(ledPin, HIGH);   // if sensor is LOW, then turn on
     }else{
        digitalWrite(ledPin, LOW);    // if sensor is HIGH, then turn off
the led
     }
}
```

This is a reference chart for the mapping from the output voltage to the NTU according to different temperature. e.g. If you leave the sensor in the pure water, that is NTU < 0.5, it should output “4.1±0.3V” when temperature is 10~50℃.



characteristic curve “Voltage ----Temperature

Note: In the diagram, the unit measuring turbidity is shown as NTU, also it is known as JTU (Jackson Turbidity Unit), 1JTU = 1NTU = 1 mg/L. Refer to Turbidity wikipedia

TDS Water Quality Detection Sensor

（Model：MW-TDS101）

Manual

Version：1.0

Valid Date：2021-11-26

郑州炜盛电子科技有限公司

Zhengzhou Winsen Electronic Technology Co., Ltd

Statement

Thanks for purchasing our product. In order to let customers use it better and reduce the faults caused by misuse, please read the manual carefully and operate it correctly in accordance with the instructions. If users disobey the terms or remove, disassemble, change the components inside of the sensor, we shall not be responsible for the loss.

The specific such as color, appearance, sizes &etc, please in kind prevail.

We are devoting ourselves to products development and technical innovation, so we reserve the right to improve the products without notice. Please confirm it is the valid version before using this manual. At the same time, users' comments on optimized using way are welcome.

Please keep the manual properly, in order to get help if you have questions during the usage in the future.

Zhengzhou Winsen Electronics Technology CO., LT

_

MW-TDS101 TDS Water Quality Detection Sensor

Profile

MW-TDS101 is an online water quality detection sensor that can be used to detect the content of total dissolved solids (TDS) in water to judge the cleanliness or pollution of water.

The unit of measurement for TDS is mg/L, which indicates how many mg of dissolved solids are dissolved in 1L of water. The higher the TDS value, the more dissolved solids the water contains.

Figure 1：TDS sensor

Sensor characteristics

High precision, fast response, good stability, small size and easy installation.

Main Application

It is widely used in laboratory scientific research, water purifier, lake water detection and other TDS detection.

Parameter

Table 1

Item	Parameter
insulation resistance	≥50MΩ（not exposed
measurement range	0-2000ppm
measurement accuracy	±5% F.S.
Operating temperature	≤70℃
Operating voltage	≤5.0V
Product Specifications	quick connect-2
Cable length	58cm

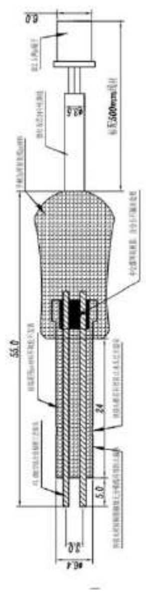


Figure 2:Sensor Structure

Instructions

1. Connect the TDS probe to the TDS sensor module.

2. Power on the TDS sensor module and put the TDS probe into the solution to be tested for testing.

3. After the test is completed, rinse the sensor electrode end with a small amount of pure or deionized water.

4. Dry the cleaned sensor and install a protective cover on the electrode end.

Cable connection

Table 2

Cable color	Definition
Blue（central core）	+
Cable（shielded network cable）	—

Precautions

◆The sensor electrode end must be cleaned before use.

◆TDS probe should not be placed too close to the edge of the container, otherwise it will affect the reading.

◆The TDS probe head and wire are waterproof and can be immersed in water, but the connection interface and signal adapter board are not waterproof, so pay attention to waterproofing when using.

◆After the test is completed, be sure to wipe off the residual water on the probe, otherwise it will affect the test accuracy in the next test.

◆The electrode head should be kept clean during long-term storage, and the sensor should be put back in the box and stored at room temperature.

Zhengzhou Winsen Electronics Technology Co., Ltd
Add.: NO.299 Jin Suo Road, National Hi-Tech Zone, Zhengzhou, 450001 China
Tel.: 86-371-67169097 Fax: +86- 371-60932988
E-mail: sales@winsensor.com
Website: www.winsen-sensor.com

ANNEXURE

A. IUPPC Pictures


CERTIFICATE
CERTIFICATE
CERTIFICATE
POWER SUPPLY


POWER SUPPLY

B. Ignite Funding:

#	FYP Code	FYP Title	Department	Team Lead	Semester	Supervisor Name
18	NGIRI-2023-19078	' ANTI-COLLISON AND DISTANCE ESTIMATION SYSTEM FOR VEHICLES DURING FOGGY WEATHER'	Electrical	Aamir Munir	7	Syed Ahsan Raza
19	NGIRI-2023-19179	'Hand Gloves Speech Conversion for paralysis [illegible]	Electrical	Muhammad Abdullah	8	Zeeshan Karimi
20	NGIRI-2023-19398	'E tongue taste sensor for quality analysis using machine learning'	Electrical Engineering	Tasneem Mustansir	7	Engr Shoaib Hussain Zaidi
21	NGIRI-2023-19433	'Embedded System Based Packaging and Filling Machine'	Electrical Engineering	Waleed Hussain	7	Dr Engr Zahid Ali
22	NGIRI-2023-20625	'Ground servallance robot for military'	Electrical Engineering	Ghazanfar Ali	8	Engr Jawaid Ali

C. Turnitin Report (Less than 19% plagiarism)

Thesis Report

ORIGINALITY REPORT

10%	8%	6%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	dx.doi.org Internet Source	1%
2	Submitted to Higher Education Commission Pakistan Student Paper	1%
3	sdd.spc.int Internet Source	1%
4	worldwidescience.org Internet Source	1%
5	Noelia Urseler, Romina Bachetti, Fernanda Biolé, Verónica Morgante, Carolina Morgante. "Atrazine pollution in groundwater and raw bovine milk: Water quality, bioaccumulation and human risk assessment", Science of The Total Environment, 2022 Publication	1%
6	Submitted to University of Leeds Student Paper	1%
7	Jumpei Yoshimatsu, Kiyoshi Toko, Yusuke Tahara, Misaki Ishida et al. "Development of	<1%

Classification of Breast Cancer", IETE Journal of Research, 2020

Publication

D. Summary report of seminars + workshops attended in FYP-1

S.No	Seminar/Workshop	Resource Person	Venue	Online/ Physical	Date	Time
1	IIoT-Industry Revolution 4.0	Syed Ahmed Raza Naqvi	PITAC, Karachi	Physical	8 Nov 21	4pm to 7pm
2	Condition Monitoring Of Generator & Motor	Engr. Ghulam Murtaza	Main Auditorium	Physical	13 Jan 21	11am to 1pm
3	Electrical Distribution System Considering Uncertainties	Dr. Mahesh Kumar	Main Auditorium	Physical	19 Feb 21	2pm to 5pm
4	Industry Automation Workshop	Engr. Tabish Ali	Mind-storm Engineering	Physical	24 Feb 21	11am to 1pm
5	Wireless Integrated Network Sensors (WINS)	Dr. Mahiddin	Zoom Meeting	Online	8 Apr 21	11am to 1pm
6	5G Mobile Technology	Professor. Nishant Aggarwal	Zoom Meeting	Online	21 Apr 21	2pm to 5pm
7	Artificial Intelligence A.I	Mr Muhammad Talha	Mind-storm Engineering	Physical	12 May 21	10am to 3pm
8	CLOUD COMPUTING	Miss Belle	Huawei seeds for the future 2023	Online	15 Oct 21	3pm to 5pm
9	Machine Learning and its Types	Miss Belle	Huawei seeds for the future 2023.	Online	16 Oct 21	3pm to 5pm
10	Sustainable Environment	Miss Belle	Huawei seeds for the future 2023.	Online	17 Oct 21	3pm to 5pm

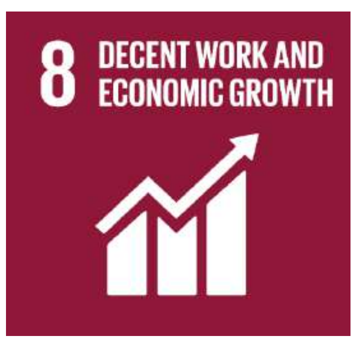
E. Feedback on PLOs covered

F. Student Feedback Form G. **PLOs Attainment** H. In Final Year Project (FYP)			
PLO#	**PLO Attribute**	**PLO Statement**	**Feedback on PLO Attainment**
PLO-1	**Engineering Knowledge**	An ability to apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems.	In this FYP, Electrical Electronics Engineering knowledge is applied for obtaining results using various types of sensors.
PLO-2	**Problem Analysis**	An ability to identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.	The problem faced by industries like food, beverages and pharmaceuticals, is that they are not able to sense the characteristics of sample such as; sourness, astringency, bitterness, saltiness, pH, TDS, turbidity and umami from a single device. This way sample undergoes different procedure by which quality and quantity is compromised. The solution to this is E-tongue taste sensor.
PLO-3	**Design/ Development of Solutions**	An ability to design solutions for complex engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.	The project was initially designed as a sketch on paper that how it will look when completed, after analyzing the design feasibility, we gathered components and the material required for developing it. The project is currently designed on a metal frame where the sensors are fixed on the acrylic disk which dips inside the sample.
PLO-4	**Investigation**	An ability to investigate complex engineering problems in a methodical way including literature survey, design and conduct of experiments, analysis and interpretation of experimental data, and synthesis of information to derive valid conclusions.	We did deep investigation to collect the relevant data regarding the sensor which mimics human tongue. In investigation it was clear that this is valuable for industries and this sensor developing based on research paper is great approach.

PLO-5	**Modern Tool Usage**	An ability to create, select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling, to complex engineering activities, with an understanding of the limitations.	The project is based on Arduino mega, and we have used sensors which are compatible with Arduino. Each sensor's programming was performed and initial results were obtained on Arduino IDE' serial monitor.
PLO-6	**The Engineer and Society**	An ability to apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solution to complex engineering problems.	The complex engineering problem solution has been achieved for the society by applying in depth knowledge of engineering principles and mechanism. As the taste sensors were developed on base of a research paper for the better quality products by industries for society.
PLO-7	**Environment and Sustainability**	An ability to understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate knowledge of and need for sustainable development.	The FYP focuses on providing good quality products for the consumers. As E-tongue can detects spoilage and toxic compound presences by its taste is need for sustainable environment.
PLO-8	**Ethics**	Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.	In this project we did research with permission and molded the idea according to our domain and requirement of our project. We came out with a unique idea and haven't copied some else's work.
PLO-9	**Individual and Team Work**	An ability to work effectively, as an individual or in a team, on multifaceted and /or multidisciplinary settings.	Our FYP team comprises of three individual members and each member has knowledge and teamwork abilities. Tasks are conveyed by the group leader and made sure that the assigned tasks are performed. Individually tasks are assigned so that each member's individual performance could come across and could be improved.
PLO-10	**Communication**	An ability to communicate effectively, orally as well as in writing, on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and	Communication is leaded by the group leader via email, WhatsApp, call, etc. Using these channels every group member participated and updated the group leader about their respected tasks. Suggestion and improvements are discussed mutually.

		give and receive clear instructions.	
PLO-11	**Project Management and Finance**	An ability to demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments, business practices, such as risk and change management, and understand their limitations.	Our project is managed by our supervisor's guidance and assigning of different tasks and group leader distributing all the tasks among group members. The tasks are given on the basis of individual's skills and knowledge regarding that specific area of interest, the tasks include hardware, software, written and physical market research. The FYP finance is equally divided between all group members.
PLO-12	**Lifelong Learning**	An ability to recognize importance of, and pursue lifelong learning in the broader context of innovation and technological developments.	In this FYP our 4 years of knowledge and skills are used from literature review to an idea, then shaping an idea as a product. The in between research methodologies will help in life ahead for further studies and pursuing studies similar to this FYP. Dealing with diverse background group members and foreigners as an assistance to develop sensors and working in a team is lifelong learning for an engineer like us to survive in this century of advancements.
FYP Students Name: Tasneem Mustansir Signature: ___________ FYP Students Name: Saleeem M Shaikh Signature: ___________ FYP Students Name: Ajlal Hyder Signature: ___________			Supervisor Name: Engr. Shoaib Hussain Signature:_________________ Date:_____________________

I. Feedback on SDGs addressed

Students' Feedback Form Sustainable Development Goals (SDGs) Implementation In Final Year Project		
Prescribed SDGS	SDGs Attained	Feed Back
		Goal no - 03 which is Good Health and Well-Being is achieved by E-tongue taste sensor as it can help to reduce the use of toxic compounds in the edibles items.
		Goal no – 6 Clean water and sanitation is achieved by Our device as it can help to monitor the quality of water.
		Goal no - 08 Decent work and economic growth is achieved as E-tongue taste sensor device can help local industries to grow and this can lead to economic growth.

		Goal no - 09 Industry, Innovation and Infrastructure is achieved as E-tongue taste sensor device is constructed in Pakistan can reduce its cost and help in improving quality of products of pharma and food companies.
		Goal no - 12 Responsible consumption and production is achieved as These numbers could be reduced by usage of E-tongue taste sensor because manufacturing of flawed sample can be reduced.

J. Feedback on CEP + PBL

<table>
<tr><td colspan="2">Student Feedback Form
Exposure of Problem Based Learning (PBL)
in Final Year Project (FYP)</td></tr>
<tr><td>**FYP Title:**
E-Tongue Taste Sensor for quality analysis using Machine learning</td><td>**Program/Batch:** BEE(ELE)/19-B
Offering Semester: 8th Semester</td></tr>
<tr><td colspan="2">*Remarks on exposure of Problem Based Learning in FYP Course by FYP Students:*

The problem was analyzed through research papers and journals that by industries like food, beverages and pharmaceuticals, is that they are not able to sense the characteristics of sample such as; sourness, astringency, bitterness, saltiness, pH, TDS, turbidity and umami from a single device. This way sample undergoes different procedure by which quality and quantity is compromised. The solution to this is E-tongue taste sensor. We opt to make our custom sensors based on the research paper. To cope with overcome it market research was carried out for the searching pf components, testing the components, getting their codes merged with Arduino. We learned to perform tweaking and calibration of sensors with the guidelines in the manufacturer's provided data sheets in case of an irregularity in results.</td></tr>
<tr><td>FYP Students Name: Tasneem Mustansir Signature:___________
FYP Students Name: Saleem M Shaikh Signature:___________
FYP Students Name: Ajlal Hyder Signature:___________</td><td>Supervisor Name: Engr. Shoaib Hussain
Signature:_________________
Date:_____________________</td></tr>
</table>

Student Feedback Form

Exposure of Complex Engineering Problem (CEP)

in Final Year Project (FYP)

FYP Title: E-Tongue Taste Sensor for quality analysis using Machine learning	**Program/Batch:** BEE(ELE)/19-B **Offering Semester:** 8th Semester

Remarks on exposure of Problem Based Learning in FYP Course by FYP Students:

Achieving a breakthrough in solving a complex engineering problem, we embarked on a journey to develop the E-tongue taste sensor device, driven by a foundation of knowledge and extensive research papers. Our endeavor was not without its challenges. Initially, we grappled with the intricacies of creating a sensor capable of mimicking the human sense of taste, requiring a profound understanding of chemistry, electronics, and sensory perception. Countless hours were dedicated to analyzing research papers and consulting experts to refine our approach. We faced hurdles such as sensitivity issues, calibration complexities, and ensuring the device's compatibility with various tastes. Through unwavering determination, collaborative teamwork, and iterative testing, we overcame these obstacles. Today, our E-tongue taste sensor device stands as a testament to the power of knowledge, research, and perseverance, revolutionizing fields ranging from food science to healthcare with its remarkable capabilities.

FYP Students Name: Tasneem Mustansir	Signature:__________	Supervisor Name: Engr. Shoaib Hussain
FYP Students Name: Saleem M Shaikh	Signature:__________	Signature:________________
FYP Students Name: Ajlal Hyder	Signature:__________	Date:____________________

K. Feedback form from related Industry

Industry Feedback Form

Name of Industry:	Sami Pharmaceuticals Pvt. Ltd.
Name of Supervisor/Concerned Person in Industry:	Danish Waheed Almuazi
Contact No./Email of Concerned Authority	0332-3607226
Type of Industry	Pharmaceuticals

Feedback from Industry

- o Strongly Recommended
- ✓ Partially Recommended
- o Not Recommended

Comments:

The project appears to be quite innovative in the field of food/drug Quality testing and analysis, it will help reach a specific taste, come up with better manufacturing process and ingredient selection etc. The applications of the electronic tongue for evaluating the taste of products are remarkable in the industry because taste attributes composing the sensory profile of products are key factors for their success among consumers. Thus, industries frequently utilize taste analysis, during the formulation or the product development steps.

Signature:

Date: 25/11/2022

L. Poster of FYP